TWO-PHASE EXCITATION LINEAR MOTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001]   The present invention relates to a two-phase excitation linear motor.

2. Description of the Related Art

[0002]   A linear motor has a simple structure, comprises a small number of parts, and drives a moving body linearly, and its drive is precise and quick.   The linear motor is widely applied to linear driving devices and positioning devices in all fields such as exposing devices for manufacturing semiconductors, and highly precise machine tools.

[0003]   In a general liner motor, as shown in Fig. 8, a current is allowed to flow through a coil unit (a moving body in this example) Ci placed between magnet rows Mg opposing to each other (fixed body in this example), and a Lorentz force generated drives the coil unit Ci.   The magnet rows Mg are arranged such that the direction of a pair of an N pole and an S pole opposing to each other is altered one by one as shown in Fig. 9.   A distance between the closest pairs of N/S poles facing in the same direction is referred as a magnetic

pole pitch.   A sinusoidal magnetic flux density distribution is generated between

the magnet rows Mg where the magnetic pole pitch is one cycle.   The magnetic

pole pitch after normalization is represented as 2π.

[0004]   The individual single coils 2 for constituting the coil unit Ci are in an

approximately rectangular ring-like shape (a racetrack shape) as a whole as

shown in Fig. 10.   Two sides of the four sides of this rectangle opposing to each

other in a direction perpendicular to a traveling direction function as a pair of

effective conductors 4a and 4b for contributing to generating a thrust force for a

moving body in a linear motor.   The other two sides opposing to each other form

a pair of connecting conductors 6a and 6b for connecting between the effective

conductors 4a and 4b, and these parts do not specifically contribute to generating

a thrust force for the linear motor.

[0005]   When a current is allowed to flow through the single coil 2, the

directions of the current are opposite to each other between the effective

conductors 4a and 4b (indicated as U and U macron).   Thus, because the signs

of the magnetic fluxes are opposite to each other, when the distance T1 between

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the effective conductors 4a and 4b is set to a distance corresponding to π, the thrust force becomes twice as much as that generated on one effective conductor 4a or 4b.

[0006] It is necessary to provide a constant thrust force wherever the single coil 2 may be positioned along the magnet rows Mg for operating the linear motor smoothly. Because the magnetic flux density has the sinusoidal distribution, it is impossible to use one single coil for providing a constant thrust force in whatever way the current may be adjusted. It is necessary to connect the multiple single coils placed with intervals as one pole.

[0007] Three phases of (three) single coils 2U, 2V, and 2W are arranged such that their positional phases are displaced by an amount corresponding to $(2/3)\pi$ to one another for using them as one pole in a three-phase excitation motor as shown in Fig. 11. Then, when a current with a phase matching the phases of the magnetic flux densities at the effective conductors 4a and 4b of the individual single coils 2U, 2V, and 2W is allowed to flow therethrough as shown in Fig. 12, a

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constant thrust force can be obtained even if the positions of the three single coils

2U, 2V, and 2W (a coil unit Ci3 as a whole) move.

[0008]   On the other hand, two single coils 2A and 2B are displaced by an

amount corresponding to $\pi/2$ as a positional phase to form one pole for a

two-phase excitation motor as shown in Fig. 13.   A distance between the two

single coils 2 corresponds to π, and the single coil itself is identical to that for the

three-phase excitation motor.   Then, when a current with a phase matching the

phases of the magnetic flux densities at the effective conductors 4a and 4b is

allowed to flow through the individual single coils 2A and 2B as shown in Fig. 14,

a constant thrust force can be obtained even if the positions of the two single coils

2A and 2B (a coil unit Ci2 as a whole) move.

[0009]   Because three-phase excitation motors can maintain a motor

constant (N/$\sqrt{W}$: a thrust force provided with an equivalent current) high,

three-phase excitation motors are used more than two-phase excitation motors in

general.

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[0010]   However, the two-phase excitation motors can be applied to an area

of the applications where the three-phase excitation motors cannot meet a

dimensional requirement.

[0011]   When the three-phase excitation motor or the two-phase excitation

motor is structured such that multiple single coils for the individual phases are

simply piled up as shown in Fig. 11 or Fig. 13, the distance M3 or M2 between the

magnet rows opposing to each other increases, thereby decreasing the magnetic

flux density.   It is necessary to arrange the effective conductors for the individual

phases in a single row, thereby minimizing the distance M2 or M3 between the

magnet rows Mg, resulting in constituting an effective linear motor.   However, a

simple racetrack shape as in Fig. 10 prevents arranging the effective conductors

4a and 4b in a single row because of the existence of the connecting conductors

6a and 6b.   There have been different types of proposals for the arrangement

while the mutual interference between the connecting conductors 6a and 6b is

avoided as much as possible.

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[0012]   Because it is primarily required for the two-phase excitation motors to reduce the size as described before, a method to arrange two single coils 2A and 2B corresponding to the A phase and the B phase separately in the same row while the coils are maintained to have the racetrack shape as shown in Fig. 15 is adopted especially to maintain the distance between the magnet rows as short as possible.

[0013]   When the two single coils 2A and 2B are separated while their phases in the magnetic flux density are being maintained, they can function as a two-phase excitation motor.   A form where single coils are arranged separately is referred as a "separate type" two-phase excitation motor for convenience in the present specification.   Though Fig. 15 shows a case where two single coils are separated by $(2k+1/2)\pi$ (k=1, 2, 3, ...), the phases of the individual single coils 2A and 2B should be opposed to each other when they are separated by $(2k-1/2)\pi$ as shown in Fig. 16.

[0014]   Fig. 17 shows an example of the applications.

[0015]   A main motor is indicated as a symbol 12 in Fig. 17, and is constituted with a conventional three-phase excitation motor.   Because a coil unit 12Ci for

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the main motor 12 is used with multiple poles in general, a wiring harness 14 for

wiring the coil unit 12Ci becomes thick and heavy, and becomes a resistance

when the coil unit 12Ci for the main motor 12 travels. Then, a separate type

two-phase excitation motor 16 is separately provided such that the motor 16

strides across the main motor 12 to drive the wiring harness 14 in synchronization

with the main motor 12 as shown in Fig. 17 (B). Gaps are provided between a

case 12a for the main motor 12 and a case 16a for the two-phase excitation motor

16 to prevent a contact between these cases when there is a difference between

their travels. Thus, the two-phase excitation motor 16 does not affect the travel

of the main motor 12 at all (while the motor 16 moves in synchronization with the

motion of the main motor 12). Because the wiring harness 14 is attached to the

two cases 16a for the two-phase excitation motor 16, and the wiring harness 14

does not affect the travel of the main motor 12 at all (while the harness 14 moves

in synchronous with the motion of the main motor 12).

[0016]   When a separate type two-phase excitation motor is applied in this way, the separated single coils do not cause any problems, and the separate existence becomes an advantage on the contrary.

[0017]   Though placing two single coils separately can be used as an application method for the two-phase excitation motors, the predetermined dimensions are specified for the spacing, and the arrangement of them may be very difficult in some cases.   Also, a weak thrust force is one of the major disadvantages of the two-phase excitation motors.

SUMMARY OF THE INVENTION

[0018]   The present invention was devised in view of the foregoing, and an object of the present invention is to manufacture a two-phase excitation motor where single coils satisfying a predetermined shape condition are used to form a two-phase excitation motor as "integrate type", thereby applying it while a magnetic flux density generated by magnet rows is increased as high as possible (in a form for increasing the thrust force).

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[0019]   Another object of the present invention is to provide a two-phase

excitation motor which is constituted as a separate type motor using the integrate

type coils corresponding to two poles, and can increase a thrust force by an

amount corresponding to the increased pole.   Still another object of the invention

is to provide a two-phase excitation motor which has a shape of a conventional

"separate type" two-phase excitation motor, and simultaneously provides a thrust

force more than that provided by the conventional separate type two-phase

excitation motor.

[0020]   A two-phase excitation linear motor according to a first aspect of the

present invention includes two single coils forming one pole to continuously

generate magnetic forces with a predetermined phase interval thereon, the

magnetic forces linearly driving a moving body, wherein the two single coils are

individually formed as an approximately rectangular ring-like shape where two

sides of the rectangle opposing to each other function as a pair of effective

conductors for contributing to generating a thrust force for the moving body of the

linear motor, and the other two sides opposing to each other function as a pair of

connecting conductors for connecting between the effective conductors, parts close to the ends of the effective conductors are bent at an approximately right angle with respect to a coil plane such that the pair of connecting conductors are offset from the coil plane, and extend in parallel with the coil plane where the coil plane is defined as a plane including individual centers of the pair of effective conductors, and the two single coils are integrated into one body such that one of the pair of effective conductors of one single coil is interposed between the pair of effective conductors of the other single coil while the individual single coils are combined such that the offset directions of the connecting conductors of the individual single coils are opposed to each other in a direction perpendicular to a traveling direction. By providing this two-phase excitation linear motor, the above-mentioned problems are solved.

[0021] When each of the single coils has a simple racetrack shape, the storage of the individual single coils becomes a problem if the multiple single coils are connected to form a coil unit as described before. Because a two-phase excitation motor has a lower motor constant compared with that of a three-phase

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excitation motor by nature, and it is senseless to adopt a two-phase excitation motor unless the cost or the size can be reduced, a drive constitution using racetrack-shape single coils as a separate type has been exclusively adopted.

[0022]   The present invention was intended to devise a shape of a coil to use a two-phase excitation motor not as "separate type" but as "integrate type" as one pole.

[0023]   The parts close to the ends of the effective conductors are bent at an approximately right angle with respect to the coil plane such that the connecting conductors are offset from (separated in parallel with) the coil plane in the single coil according to the present invention.   Then, the two single coils are integrated into one body such that one of the pair of effective conductors of one single coil is interposed between the pair of effective conductors of the other single coil while the individual single coils are combined such that the offset directions of the connecting conductors of the individual single coils are opposed to each other in a direction perpendicular to the traveling direction.

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[0024]   As a result, the individual effective conductors of the two single coils are arranged in a single row, and simultaneously, the length of the offset of the connecting conductors decreases further. Thus, when the single coils are used to form a coil unit, the projected area of the connecting conductors on a transverse section in the traveling direction is decreased further while they are still the integrate type. Also, because the integrate type forms "one pole", and a part corresponding to this one pole can form a motor, the size of an entire coil unit can be decreased remarkably.

[0025]   A second aspect of a two-phase excitation linear motor according to the present invention has a characteristic that the transverse section of the connecting conductors is in an approximately trapezoidal shape including parallel sides approximately perpendicular to the coil plane, and a tilted side opposing to the coil plane and being tilted in a direction opposite to the direction of the offset of the connecting conductors in the extending state. This allows manufacturing a more compact coil unit.

[0026]   A third aspect of a two-phase excitation linear motor according to the present invention has a characteristic that two or more integrated two-phase (two) single coils are placed in separate positions for multi-polarization.

[0027]   Though this arrangement embodiment appears similar to that of the separate type two-phase excitation motor, the present invention largely differs from the "separate type" in a point that the individual two coils forms "one pole", and the entire device is two-phase multi-polarized, thereby enabling to obtain double thrust force.

[0028]   A fourth aspect of a two-phase excitation linear motor according to the present invention includes two single coils forming one pole to continuously generate magnetic forces with a predetermined phase interval thereon, said two single coils being placed separately, the magnetic forces linearly driving a moving body. Here, each of the single coils comprises two sub-single coils each formed as an approximately rectangular ring-like shape where two sides of the rectangle opposing to each other function as a pair of effective conductors for contributing to generating a thrust force for the moving body of the linear motor, and the other

two sides opposing to each other function as a pair of connecting conductors for connecting between the effective conductors. The two sub-single coils are integrated into one body such that one of the pair of effective conductors of one sub-single coil is interposed between the pair of effective conductors of the other sub-single coil, while the two sub-single coils are connected to each other in series to form one connected-single coil and the two connected-single coils are separately arranged as said single coil for forming one pole.

[0029]   This arrangement also appears similar to that of the separate type two-phase excitation motor. However, the present invention differs from the conventional "separate type" in a point that the single coil at each location is not a simple racetrack-shape single coil, the single coil (to which any one of the first to third aspects of the invention is applied) is used as a "sub-single coil", the single coils are coupled to form a "connected-single coil", and the two connected-single coils are separately placed to constitute one pole while they serve as the separate type.

[0030]   Thus, another (connected-) single coil wired in series in the same way

is required to form a single pole as a two-phase excitation motor.   Therefore, it

also belongs to a category of the "separate type" two-phase excitation motors in

terms of the form.

[0031]   Because two (sub-) single coils are connected in series to form a

"one-phase" (connected-) single coil in this motor, the number of turns n for each

phase is twice as many as that of the single coil according to the conventional, or

any one of the first to third aspects of the invention.   In general, when the number

of turns n increases to obtain a large thrust force, the area of a transverse section

of the connecting conductors as well as that of the effective conductors

increases, the storage of the single coil becomes degraded, and a dimension in

terms of thickness as the single coil increases.   Thus, it is unavoidable to

increase the distance between the magnet rows accordingly.   However,

because the individual sub-single coils according to this aspect of the present

invention have the number of turns similar to that for the conventional single coil,

the dimension in terms of thickness approximately corresponds to that of one

sub-single coil, and is not so large.   Above all, because it is possible to properly

select whether the sub-single coil is used for a single coil or for a

connected-single coil, there is an advantage that a simple design change can

realize a motor having a different thrust force.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]　　The preferred embodiments will be described with reference to the

drawings, wherein like embodiments have been noted throughout the figures with

like reference numerals and wherein:

[0033]　　Fig. 1 shows a single coil of a coil unit for a linear motor according to

the present invention, where (A) is a perspective view thereof, and (B) is a section

thereof taken along a line indicated by arrows 1B of (A);

[0034]　　Fig. 2 is a perspective view showing an integrated state of a coil unit

using the single coils;

[0035]　　Fig. 3 is a sectional view corresponding to a longitudinal sectional

view taken along a line indicated by arrows III in Fig. 2 which shows an integrated

state of the coil unit using the single coils, where (A) shows a section without a

tilted side θ, and (B) shows a section with the tilted side θ;

[0036]   Fig. 4 is a schematic plan view showing an arrangement example of

the coil unit;

[0037]   Fig. 5 is a plan view showing another arrangement example;

[0038]   Fig. 6 is a schematic plan view showing an arrangement example of a

connected type coil unit;

[0039]   Fig. 7 is a table showing a comparison among characteristics of the

individual arrangement examples;

[0040]   Fig. 8 is a schematic perspective view showing a constitution of a

conventional linear motor;

[0041]   Fig. 9 is a graph showing a magnetic flux generated on the

conventional linear motor;

[0042]   Fig. 10 is a perspective view showing a single coil adopted in the

conventional linear motor;

[0043] Fig. 11 is a schematic plan view showing an arrangement example of single coils in a three-phase excitation motor;

[0044] Fig. 12 is a graph showing a state where a normalized magnetic flux density is generated on the three-phase excitation motor;

[0045] Fig. 13 is a schematic plan view showing an arrangement example of single coils in a two-phase excitation motor;

[0046] Fig. 14 is a graph showing a state where a normalized magnetic flux density is generated on the two-phase excitation motor;

[0047] Fig. 15 is a schematic plan view showing an arrangement example of single coils in a separate type two-phase excitation motor;

[0048] Fig. 16 is a schematic plan view showing another arrangement example of the single coils in the separate type two-phase excitation motor; and

[0049] Fig. 17 is a perspective view showing an application of the separate type two-phase excitation motor.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0050]   Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.

[0051]   Fig. 1 shows a single coil of a coil unit for a two-phase excitation linear motor according to an embodiment of the present invention.   (A) is a perspective view thereof, and (B) is a sectional view thereof taken along a line indicated by arrows 1B indicated in (A).

[0052]   The single coil 12 is in an almost rectangular ring-like shape as a whole, two sides of this rectangle opposing to each other function as a pair of effective conductors 14 for contributing to generating a thrust force for a moving body of the linear motor, and the other two sides opposing to each other function as a pair of connecting conductors 16 for connecting between the effective conductors 14.

[0053]   A plane including the centers of the individual effective conductors 14 is defined as a coil plane CP for convenience.

[0054]   Parts close to the ends on the effective conductors 14 are bent at an approximately right angle with respect to the coil plane CP such that the pair of

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connecting conductors 16 are offset from the coil plane CP, and extend in parallel with the coil plane CP.

[0055]   On the other hand, the transverse section of the connecting conductors 16 is in an approximately trapezoidal shape including, in this bending state, parallel sides 16a and 16b approximately perpendicular to the coil plane CP, a tilted side 16c which opposes to the coil plane CP, and is tilted in a direction opposite to the direction of the bend (the offset) of the connecting conductors 16, and a side 16d on a side opposite to the coil plane.

[0056]   As a result, because the tilted side 16c is positioned on the coil plane CP side, and the sides 16a (one of the two parallel sides 16a and 16b) and the 16d are respectively positioned on an outer periphery of the connecting conductors 16, planes perpendicular to and parallel with the coil plane CP appear on the outer periphery thereof.

[0057]   A tilt angle θ of the tilted side 16c with respect to the coil plane CP is set to approximately 15 degrees in the present embodiment.

[0058]   The section of the effective conductors 14 has a rectangular shape, and includes side surfaces 14a and 14b parallel to the coil plane CP, and outer side surfaces 14c and 14d perpendicular to them.   The tilted side 16c is positioned between a plane EP including the side surface 14a on the bent side, and the coil plane CP.

[0059]   The "trapezoid" as the sectional shape of the connecting conductors 16 is not necessarily a precise trapezoid in a geometrical sense, and the "trapezoid" of the present invention includes a shape with rounded corners or the individual sides 16a to 16d curved more or less.

[0060]   The following section describes actions of the single coil 12 based on the shape thereof while describing a constitution and actions when the single coils 12 are applied to a two-phase excitation linear motor.

[0061]   One single coil 12 forms a "one-phase" of the two-phase excitation motor in a first embodiment.   Thus, the two single coils are required for constituting the two-phase excitation motor. In the present embodiment, first, the single coils are combined such that an offset direction of connecting conductors

16Aa and 16Ab of a single coil 12A, and an offset direction of connecting

conductors 16Ba and 16Bb of a single coil 12B are opposite to each other in a

direction perpendicular to the traveling direction as shown in Fig. 2. The two

single coils 12A and 12B are integrated into one body such that one effective

conductor 14Ba of a pair of effective conductors 14Ba and 14Bb of the single coil

12B is interposed between the pair of the effective conductors 14Aa and 14Ab of

the other single coil 12A.

[0062]   An arrangement with respect to the magnet rows Mg will be described

later, and the following section describes an effect of the tilted side.   Fig. 3 shows

this integrated state. (A) shows a case where the tilt θ is not formed, and (B)

shows a case where the tilt θ is formed.   A coil unit Ci10 in (A) of Fig. 3 is more

compact than a case where conventional racetrack-shape single coils are

integrated to form a coil unit, and is constituted itself so as to provide the effect of

the present invention.   However, it is not possible to avoid interference between

the connecting conductors 16 of the single coils 12 next to each other unless a

transverse width W1 of the connecting conductors 16 with respect to the traveling

direction (a total offset width of the connecting conductors 16 being assembled) is

set to fairly large.

[0063] On the other hand, in the single coil Ci12 shown in Fig. 3 (B), the tilted

side 16c has a tilted angle θ in a direction opposite to the bent (offset) direction of

the connecting conductors 16 with respect to the coil plane CP. Furthermore, the

title side 16c is set inside (on the coil plane side) of the plane EP (see Fig. 1)

including a side surface 14a of the effective conductors 14. As a result, the

existence of the tilt angle θ allows shifting the transverse section of the

connecting conductors 16 toward the coil plane CP side largely while interference

between an outer periphery G of the bent part of the neighboring connecting

conductors 16 and the tilted side 16c is avoided.

[0064] Thus, a transverse width W2 of the connecting conductors 16 with

respect to the traveling direction (a total offset width of the connecting conductors

16 being assembled) can be reduced from the W1, and an unnecessary area

(space) R is eliminated to provide a more compact storage. This reduction

contributes to reducing the width of the linear motor LM in the transverse direction

with respect to the traveling direction, and a thicker casing may be used when the same width can be maintained, thereby enabling a more stable travel, and generating a stronger thrust force depending on a design.

[0065]   In addition, because the transverse section of the connecting conductors 16 is a trapezoid, the outer periphery of the connecting conductors 16 is perpendicular to or parallel with the coil plane CP, thereby presenting an excellent fit to a mounting member or a magnetic pole unit.

[0066]   The single coil 12 (or 10) may be manufactured with any specific way. Namely, as long as a resultant shape eventually has the shape according to the present invention, the prescribed effects of the present invention can be provided.

[0067]   The two-phase (one pole) coil unit Ci12 (or Ci10) combined in this way is arranged as shown in Fig. 4.

[0068]   The magnetic pole pitch of a fixed body is 2π, and the interval between the pair of effective conductors 14Aa and 14Ab, and the interval between the effective conductors 14Ba and 14Bb are π.   The effective conductor 14Ba of the pair of effective conductors 14Ba and 14Bb of the single coil 12B is

interposed between the pair of effective conductors 14Aa and 14Ab of the other

single coil 12A such that the effective conductor 14Ba has an interval of $\pi/2$ to the

effective conductors 14Aa and 14Ab.

[0069]   A one-pole two-phase excitation linear motor equivalent to the prior

art described in Fig. 13 or Fig. 15 in terms of the phase can be constituted in this

arrangement.   In addition, because the individual effective conductors 14Aa,

14Ab, 14Ba, and 14Bb are arranged completely as a single row on a line L1, a

distance M12 between the magnet rows can be reduced, and the magnetic flux

density increases accordingly, resulting in a one-pole two-phase excitation linear

motor with high efficiency.   Because the two single coils 12A and 12B are

combined as the coil unit Ci12, and is clustered at one position, the coil unit can

be stored in an extremely compact space compared with the conventional

separate type one-pole two-phase excitation motor, which have been used

exclusively.

[0070]   The two coil units Ci12 shown in Fig. 4 are arranged on the line L1 to

form a two-pole two-phase excitation motor as shown in Fig. 5.   This motor

appears similar to the conventional separate type one-pole two-phase excitation

motor. However, since the individual two coils forms "one pole", this motor can

provide a thrust force about twice as much as that of the integrate type one-pole

two-phase excitation motor in Fig. 4, which corresponds to the doubled poles.

[0071]   When the P coil units Ci12 are arranged with an interval of 2kπ, a

P-pole two-phase excitation motor is formed, and provides a thrust force about P

times as much as that of the motor in Fig. 4.

[0072]   Fig. 6 shows still another embodiment of the present invention.

[0073]   The "single coil" referred in the previous embodiments is considered

as a sub-single coil, and two of them are connected to form one one-phase

connected-single coil in this embodiment.

[0074]   Thus, how the coils are specifically combined has common aspects

with, and different aspects from the previous embodiments.

[0075]   The common aspects include a point that the offset direction of

connecting conductors 26Aa and 26Ab of a coil body 22A, and the offset direction

of connecting conductors 26Ba and 26Bb of a coil body 22B are opposite to each

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other in the direction perpendicular to the traveling direction, and a point that the one effective conductor 24Ba of the pair of effective conductors 24Ba and 24Bb of the coil body 22B is interposed between the pair of effective conductors 24Aa and 24Ab of the other coil body 22A.. Namely, the basic combination itself is similar to that in the previous embodiments.

[0076] However, an interval between them is not $\pi/2$, and the effective conductors 24Aa and 24Ba, and 24Ab and 24Bb are in contact with each other, respectively, in this embodiment. Both the coil bodies 22A and 22B are connected in series, and are designed such that a current flows in the same direction in the contacted effective conductors 24Aa and 24Bb, or 24Ab and 24Bb. The distances between the centers of the effective conductors 24Aa, 24Ba, and the centers of the effective conductors 24Ab , 24Bb are π, and the distances are maintained.

[0077] As a result, two coil bodies 22A and 22B form one single coil 32 with a number of turns twice as many as that of the coil body 22A or 22B. Because this single coil 32 restrains an increase of the length in a thickness direction to the

minimum while it has a number of turns twice as many as that of the individual coil

body 22A or 22B, it is not necessary to largely increase an interval M22 between

the magnet rows Mg.

[0078] Because this single coil 32 simply forms a single coil for one phase, it

is necessary to install another equivalent single coil 32 to constitute a two-phase

excitation coil. Installing another single coil 32 with a predetermined interval $2k\pi$

provides a separate type one-pole two-phase excitation linear motor as shown in

Fig. 6.

[0079] Fig. 7 is a table for showing ratios of the system length, the thrust

constant, and the motor constant of the two-phase excitation motors according to

the respective embodiments to those of the conventional racetrack-shape

one-pole separate type two-phase excitation motor. The numbers in the table

are obtained when the magnetic pole pitch is 72 mm, and the length of a linear

part of the coil is 12 mm. The thrust constant and the motor constant depend on

the distance between the magnets facing to each other, and the height of the

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magnets. Although the numbers in the table exemplify only one case, the relative

tendency in magnitude does not change.

[0080]   Because the constitution in Fig. 4 according to the present invention

realizes one-pole constitution which has characteristics almost equivalent to

those of the conventional separate type one-pole two-phase excitation motor

shown in Fig. 15, and is complete by itself as one side so that the length of the coil

unit does not increase largely, and fairly increases the efficiency.

[0081]   The constitution in Fig. 5 according to the present invention employs

multi-polarization to increase the thrust force further.

[0082]   Though the constitution in Fig. 6 according to the present invention

still requires another separate (connected) single coil, this constitution provides a

larger thrust force corresponding to the increased winding per phase.

[0083]   Because the distance between the centers of the effective conductors

of the coupled (connected) single coils is basically constant, adjusting only the

number of (sub-)single coils to be coupled on the moving body adjusts/changes

the thrust force without changing the interval between the magnet rows, namely

without changing the fixed body. Thus, this constitution is efficient in terms of ease of the design change.

[0084]   The present invention provides a low cost, compact two-phase excitation motor with a higher efficiency or a higher thrust force.